RTCA Free Flight Select Committee
Safe Flight 21 Steering Committee

Eurocontrol ADS Programme

ADS-B Technical Link Assessment Team (TLAT)

Technical Link Assessment Report
March 2001

APPENDIX K - Attachment 3

1090 MHz Extended Squitter Simulation Results
DERA/SIEM Model

Slide 1

Frankfurt Validation

Slide 2

Approach

- SIEM scenario replicated Frankfurt environment
  - Not fully possible due to lack of data
- Compare simulation outputs to recorded data

Slide 3

Frankfurt Assumptions

- Aircraft number should be the same, but DERA report significant difference
- Ground interrogator database = German database + RASCAL for other states
- TLAT antenna gain model
- Receiver of interest is advanced
  - Other receivers are today's specification

Slide 4

Results - 1

1030 MHz Interrogation Rate (Measured on-board FAA N40 aircraft).

Interrogation Type	Measured (Frankfurt Trial)		SIEM Modelling
	Range	Mean	
Mode A/C	250 to 650	350	416
Mode S	100 to 450	250	25

- Goetzenheim and other experimental Mode S radars not included in SIEM
- Underestimate number of TCAS aircraft?

Slide 5

Results - 2

Mode A/C (ATCRBS) FRUIT (Measured on-board FAA N40 aircraft).

Receiver Sensitivity	Measured (Frankfurt Trial)		SIEM Modelling
	Range	Mean	
-84dBm	15 000 to 30 000	22 000	72 518
-79dBm	6 000 to 12 000	9000	33 433
-74dBm	2 500 to 5 200	4000	14 314

- SIEM overestimated aircraft numbers?
- Limitations in N40 receiver?

Slide 6

Results - 3

Mode S FRUIT (Measured on-board FAA N40 aircraft).

Receiver Sensitivity	Measured (Frankfurt Trial)		SIEM Modelling
	Range	Mean	
-84dBm	750 to 1250	1000	576
-79dBm	300 to 700	500	275
-74dBm	150 to 500	300	133

- Goetzenheim and other experimental Mode S radars not included in SIEM
- Underestimated number of TCAS aircraft?

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Results - 4

Passive Receiver performance (on-board FAA N40 aircraft vs. Beech King)

Range (Nm)	Measured (Frankfurt Trial)		SIEM Modelling
	Range	Mean	
10	65 to 95%	80%	68%
20	30 to 85%	55%	10%
40	55-80/10 -20%	68% / 15%	1%
80	30-45/8-15%	35% / 10%	-
120	0 to 12%	5%	-

- SIEM overestimated aircraft numbers? (short range OK, long range poor)
- Similar results for N40 vs Metroliner

Slide 8

Results - 5

Langen Passive Receiver (66 degree sector) performance (vs. Beech King)

Range (Nm)	Measured (Frankfurt Trial)		SIEM Modelling
	Range	Mean	
10	75 to 100%	88%	99%
20	78 to 85%	82%	87%
40	60 to 90%	75%	50%
80	25 to 72%	55%	-
120	0 to 12%	8%	-

- SIEM overestimated aircraft numbers? (short range OK, long range poor)

Slide 9

Reasons for Divergence - 1

- Uncertainties in:
  - Non-German ground radar interrogators (Civil and military) (Especially PRFs)
  - Aircraft parameters (SIEM assumes all aircraft operate in specification)
  - Proportion of Mode S/TCAS equipage
  - Antenna gain model (unvalidated)
- Goetzenheim and other Mode S radars not in SIEM

Slide 10

Reasons for Divergence - 2

- SIEM assumed 400 a/c within 150 nm
  - Frankfurt data shows 250 a/c within 150 nm
  - Would reduce FRUIT rate by 30%
- Potential for FRUIT garble in measurements
  - SIEM does not include this
  - DERA suggests it would reduce FRUIT rate to 40%
  - Depends on N40 implementation

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Adjusted Results

Mode A/C (ATCRBS) FRUIT (Measured on-board FAA N40 aircraft).

Receiver Sensitivity	Measured (Frankfurt Trial)		SIEM Modelling with allowance made for traffic and decoder performance.	
	Range	Mean	30% traffic reduction	40% decode prob.
-84dBm	15 000 to 30 000	22 000	55 800	**22 320**
-79dBm	6 000 to 12 000	9000	25 700	**10 280**
-74dBm	2 500 to 5 200	4000	10 800	**4 320**

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Summary

- Frankfurt measurements vs SIEM model
  - Interrogation rates close or differences explainable
  - FRUIT rates too high, but differences may be exlpainable
  - More study needed to understand environment

Slide 13

Analysis of 2015 European Scenario Results

Slide 14

Main Assumptions

- 2015 aircraft and ground interrogator scenario
- Advanced 1090 decoder model
- TLAT antenna gain model
- Transmission of 4 TCPs by A3
  - (each every 1.7s – total transmission rate rises to 7.4 extended squitters/sec)
- A0/A1/A2/A3 altitude split

Slide 15

Advanced Decoder

DERA implementation in place of JHU model

Prob. Mode A/C decode (no interference): 1
Prob. Mode A/C decode (1 ATCRBS interfere): 0.75
Prob. Mode A/C decode (2 or more ATCRBS interfere): 0.5
Error detection time: 50us
Max. number of synchronous replies: 3
Prob. Mode S decode (no interference): 1
Prob. Mode S decode (1 interference): 1
Prob. Mode S decode (2 interference): 0
Receiver desensitisation: -3dB

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Receivers Modelled

Receiver type	Height	Antenna (s)	Diversity?	MTL at
A (ground omni)	30 ft	Omni	n/a	-84 dBm
B (ground directional)	30 ft	60° sector	n/a	-84 dBm
C (airborne A3 advanced)	30,000 ft	Top: 4 sector forward looking TCAS Bottom: omni	yes	-84 dBm
D (airborne A0 basic)	15,000 ft	Top: omni Bottom: omni	no	-72 dBm
E (reference)	30 ft	2.4°	n/a	-84 dBm

Although the TCAS antenna is sectorised, it receives squitters as an omni

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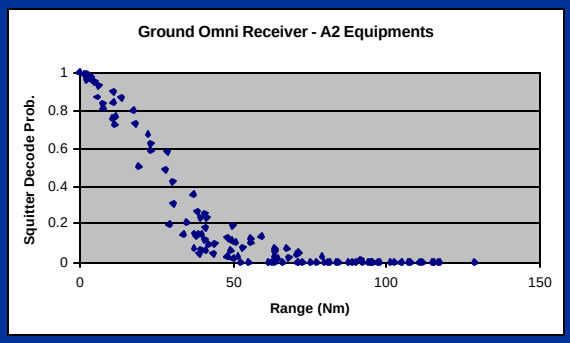
Typical SIEM Output



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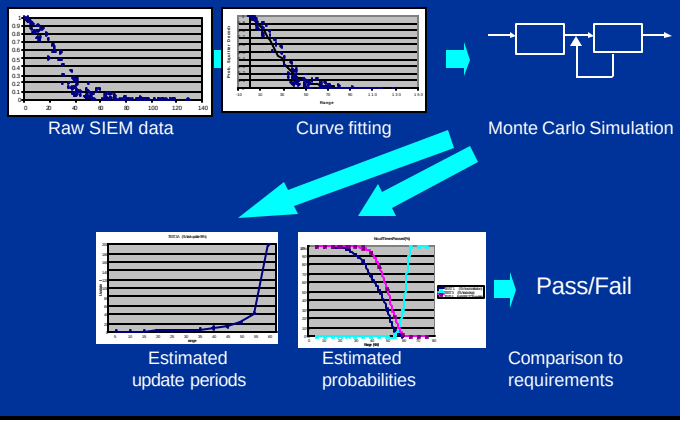
Approach to Analysis



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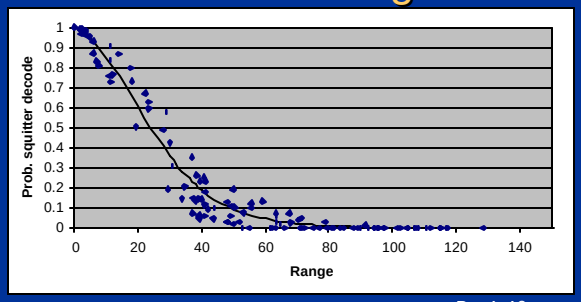
Curve Fitting



Run A, A2 range

$$y = \frac{1}{1 + x \exp(a(x-b))}$$

Slide 20

Monte Carlo Simulation

Example – SV Track Initiation

- Given Probability P of receiving squitter at range R
  - Calculate probability of receiving 4 squitters in a sample 24 s period (BDSs 05 odd & even, 08 and 09)
  - Repeat 1000 times
  - Count number of successful trials
- Repeat for different values of R

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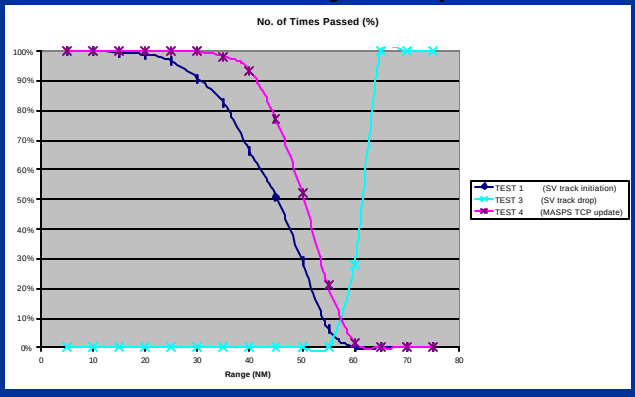
Probability Graphs



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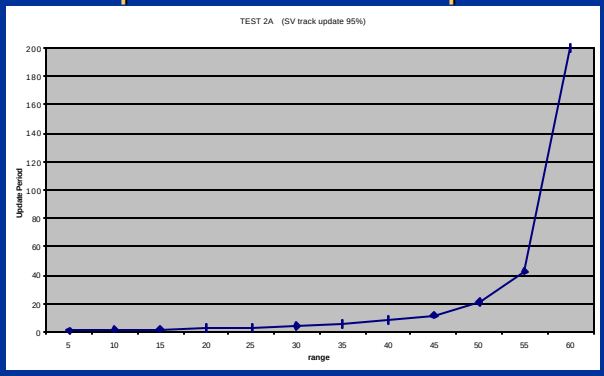
Update Period Graphs



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Tests Carried Out

SV track initiation
- Probability of initiation of SV before reaching application range
- Requires reception of 4 e.s. within 25s (Pos, 2 Vel. + ID)

SV track update
- Probability of detection of update of SV report within a period vs. range
- Requires reception of 2 e.s. (Pos. & Vel.)

SV track drop
- Track drop occurs if no e.s. are received for period of 25s

MASPS TCP update
- Requires reception of 2 e.s. TCPs within 24s

Eurocontrol TCP update
- Requires reception of the 4 e.s. TCPs.
- 95% update probability

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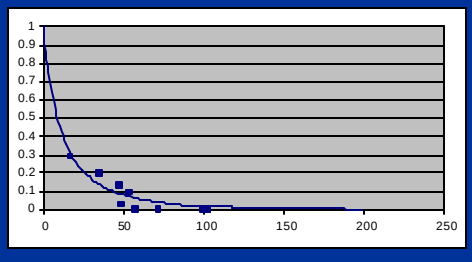
Run A, A0 range

Curve Fitting



a = 0.0161 b = 141.254

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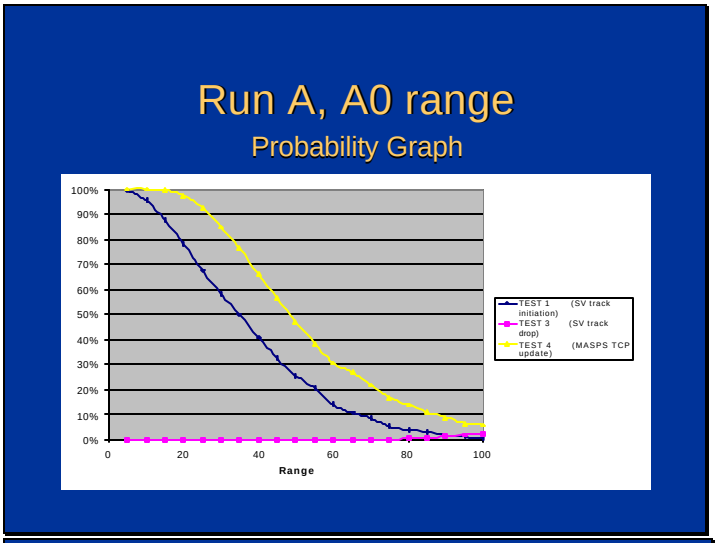

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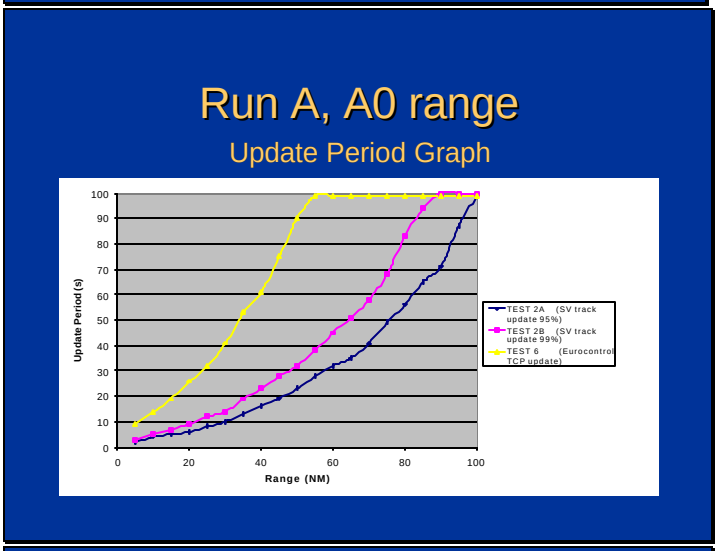

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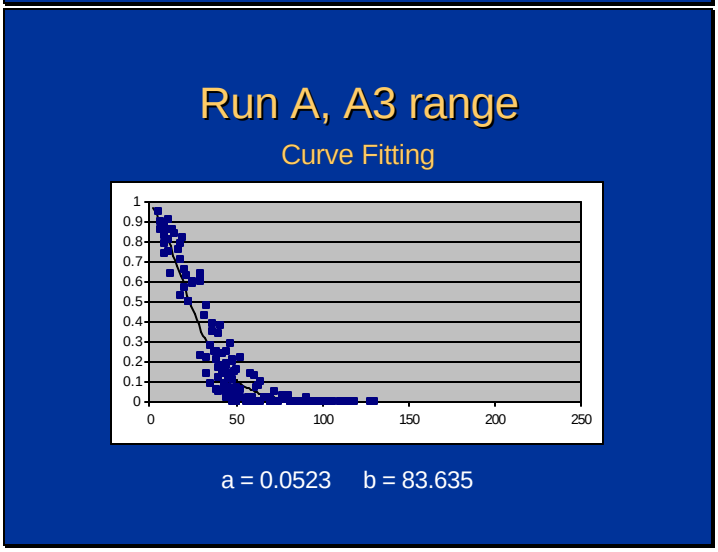

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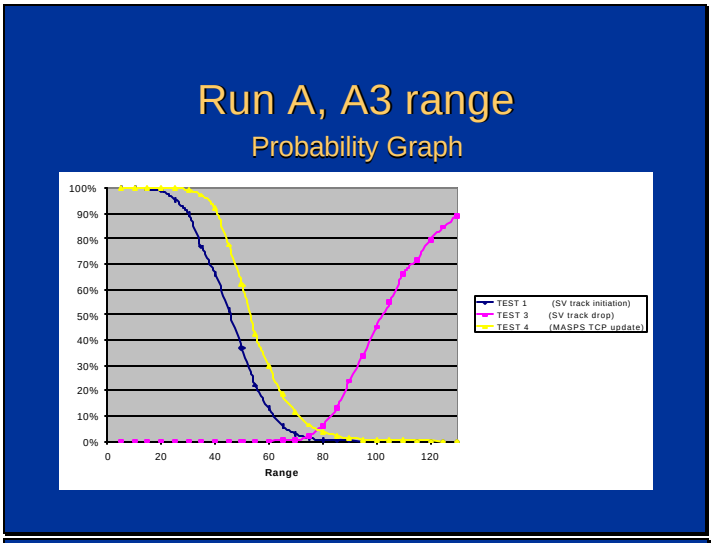

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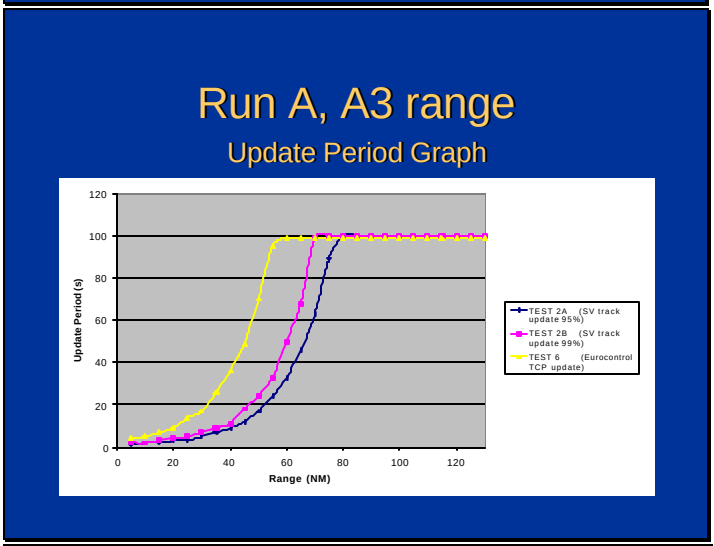

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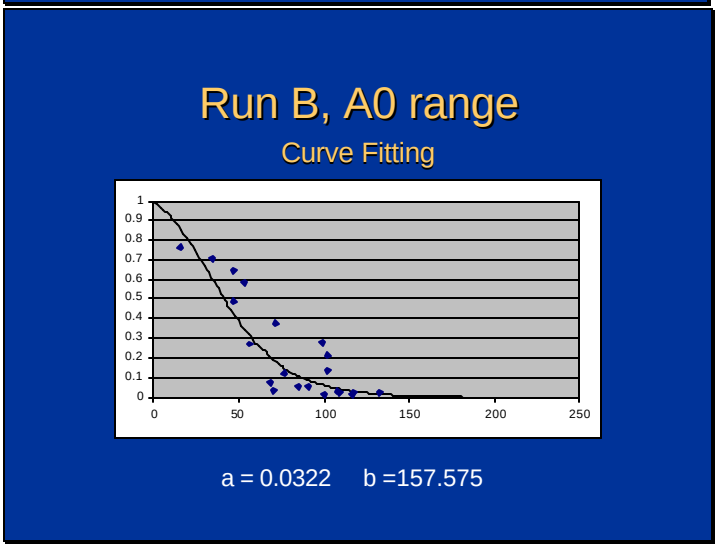

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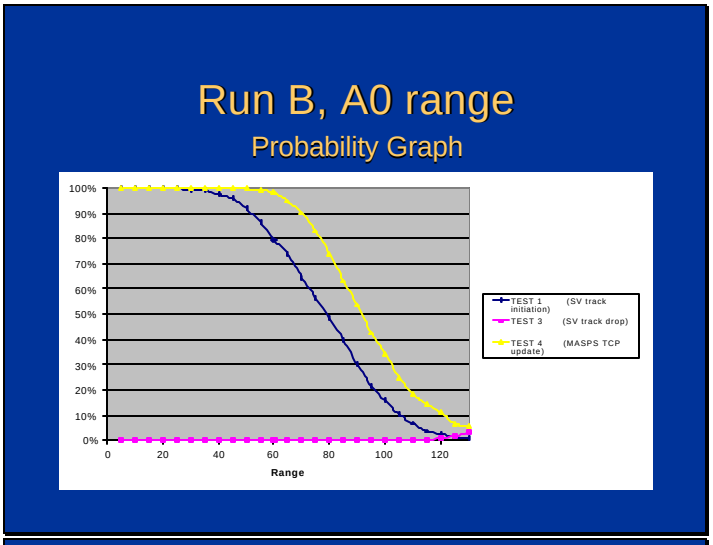

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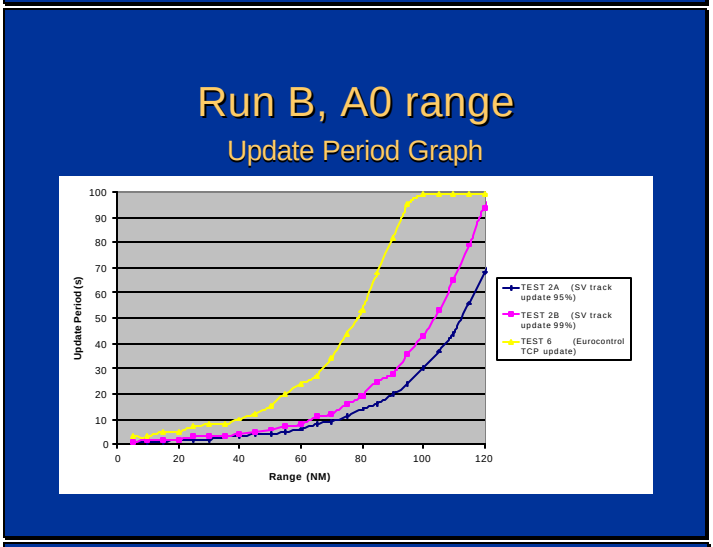

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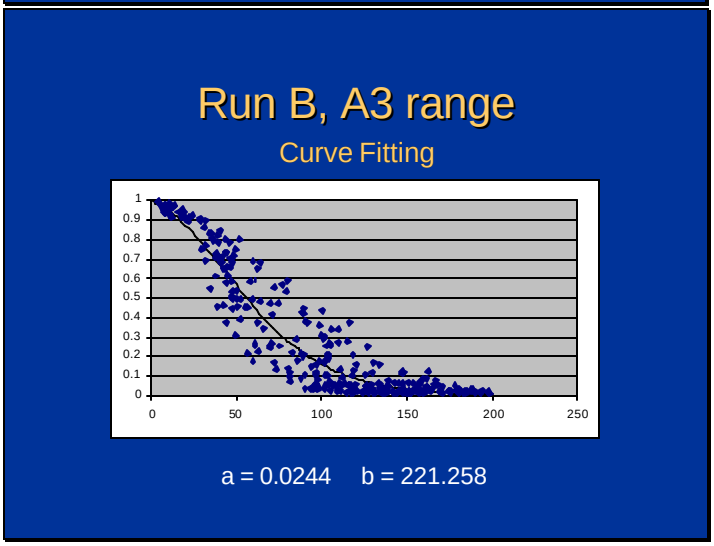

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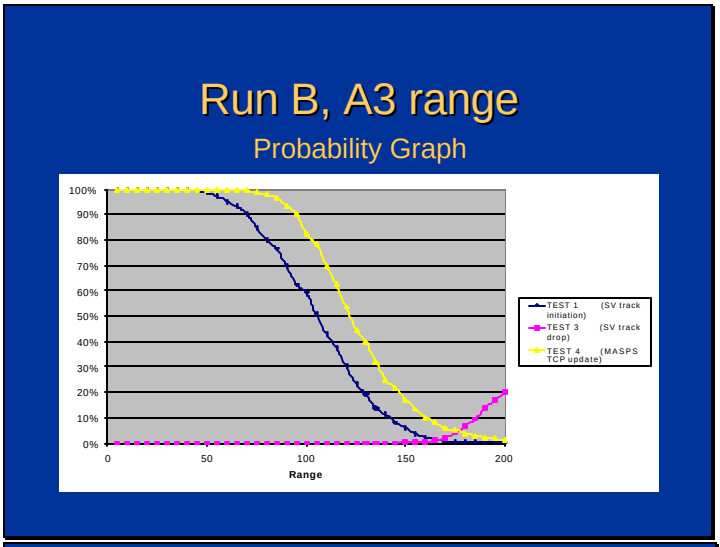

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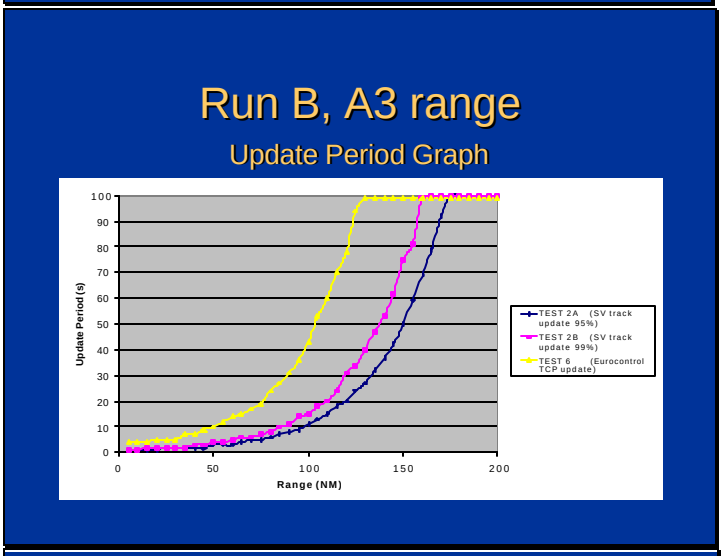

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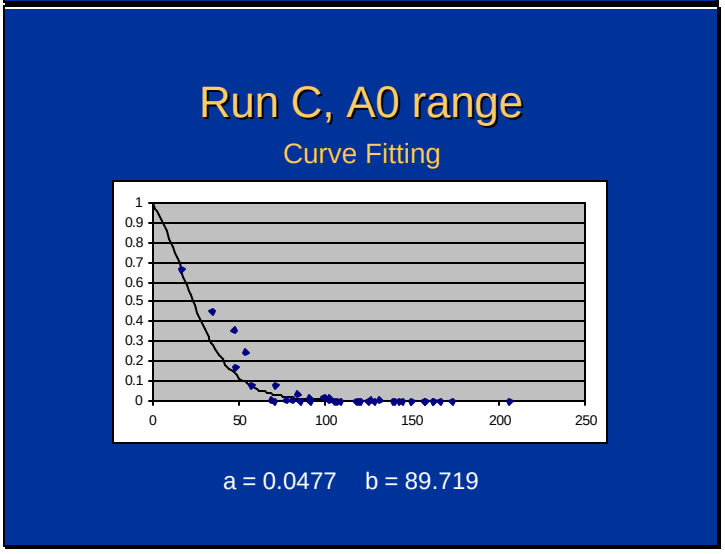

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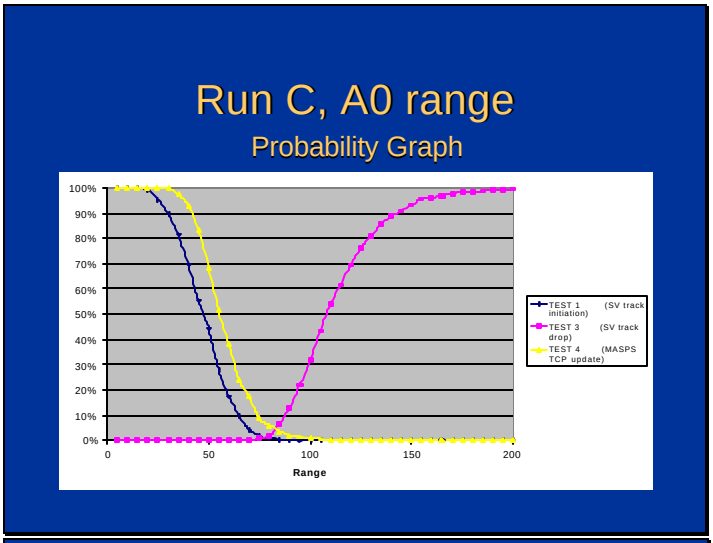

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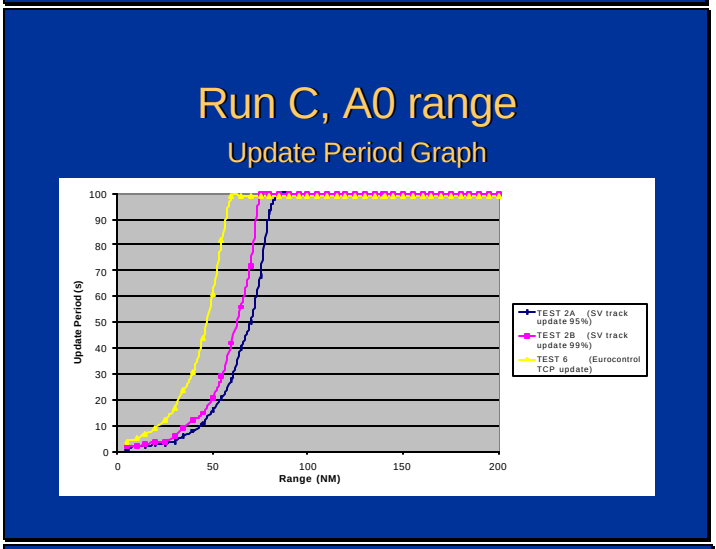

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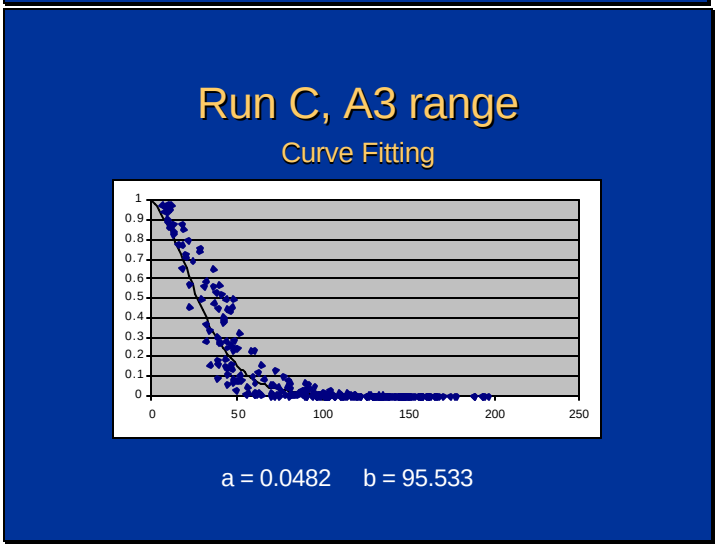

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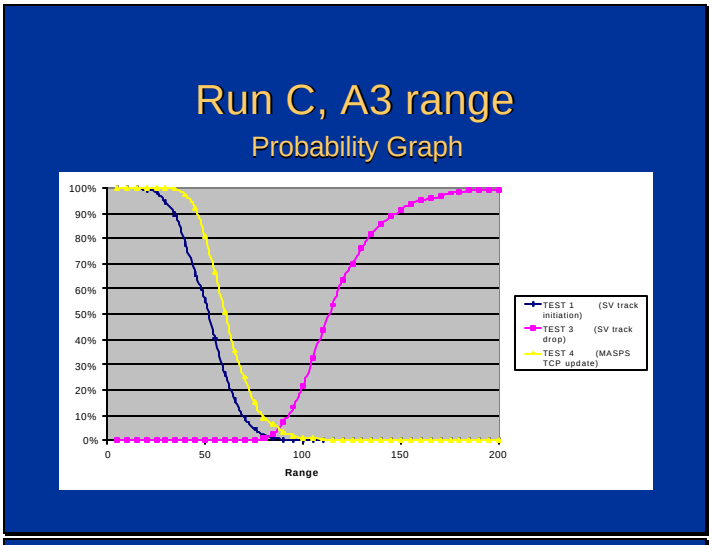

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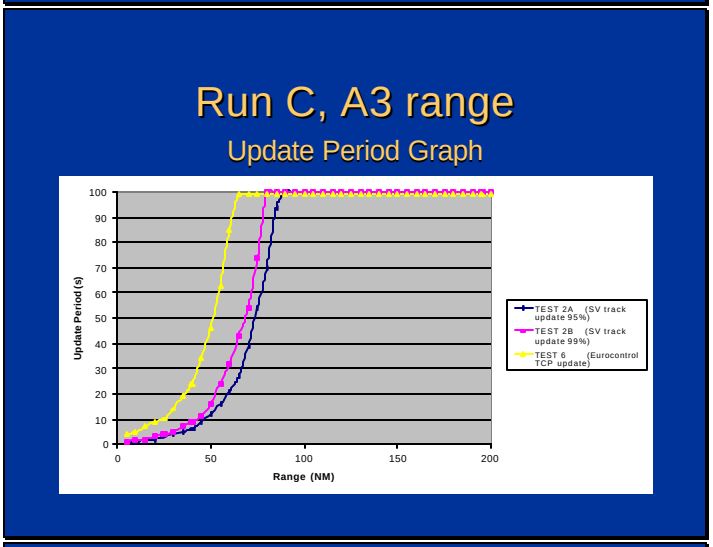

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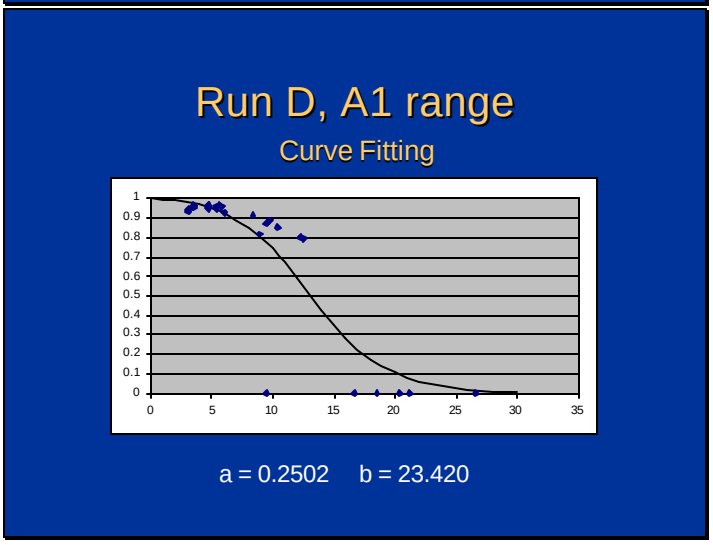

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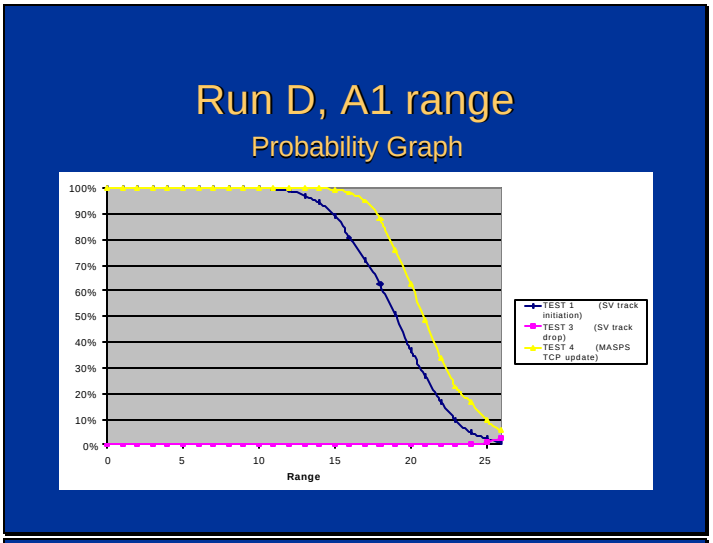

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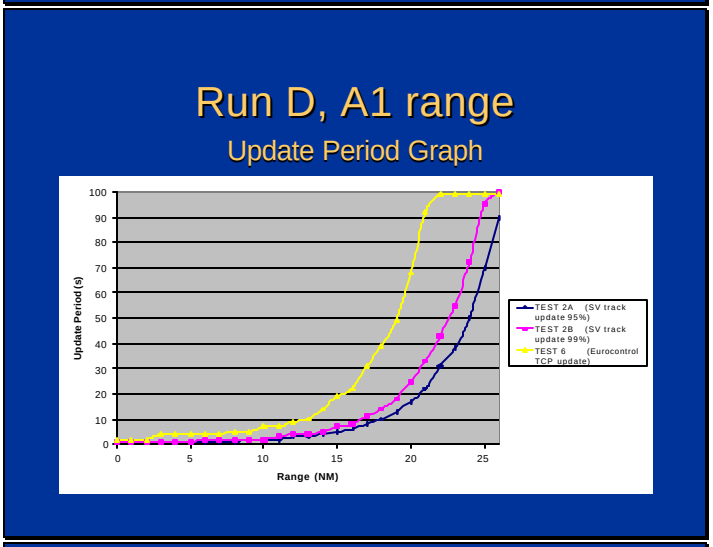

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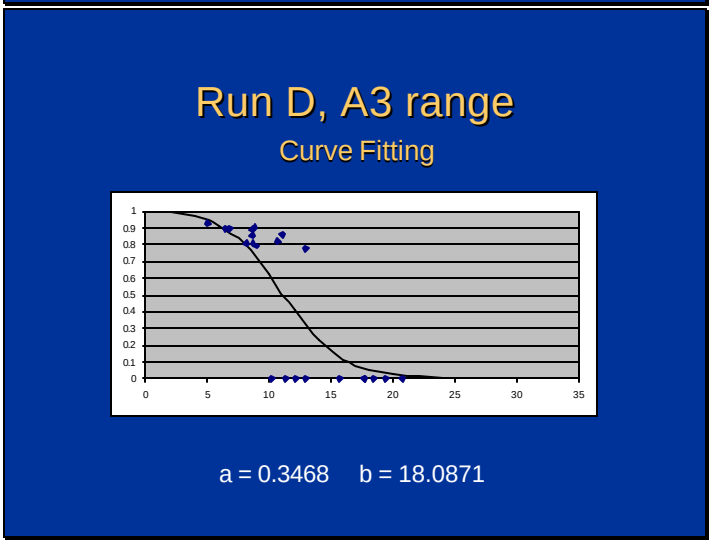

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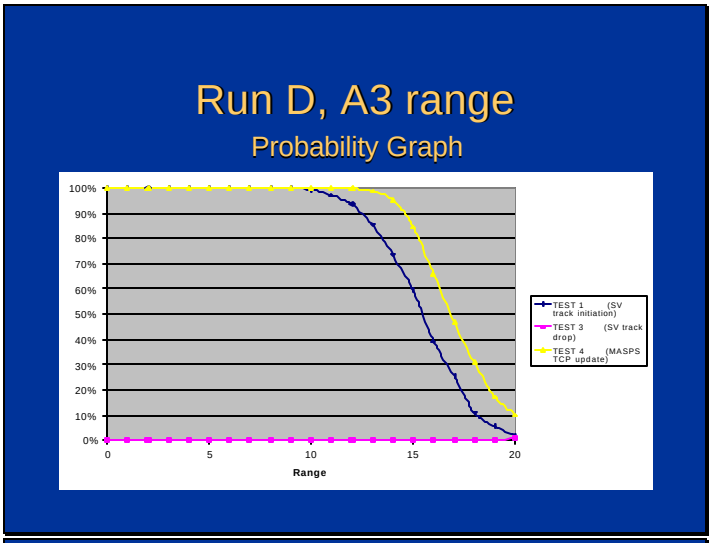

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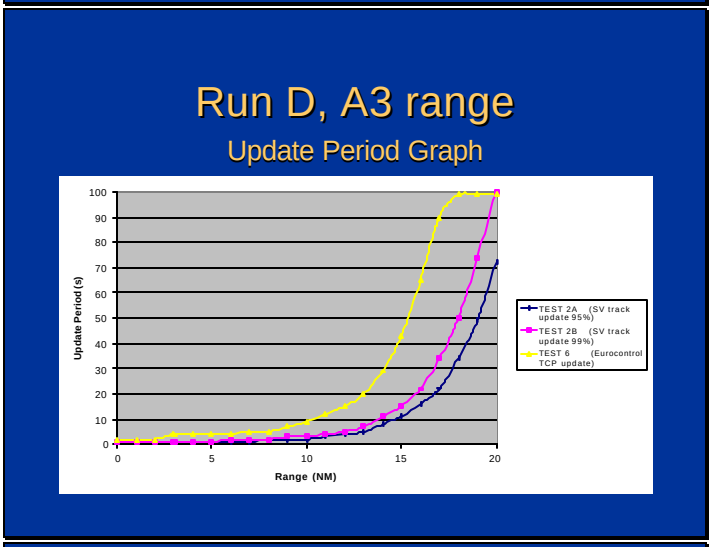

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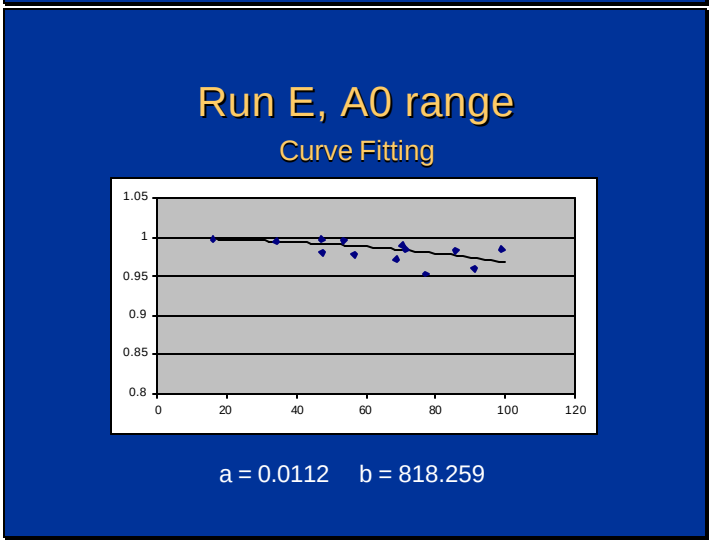

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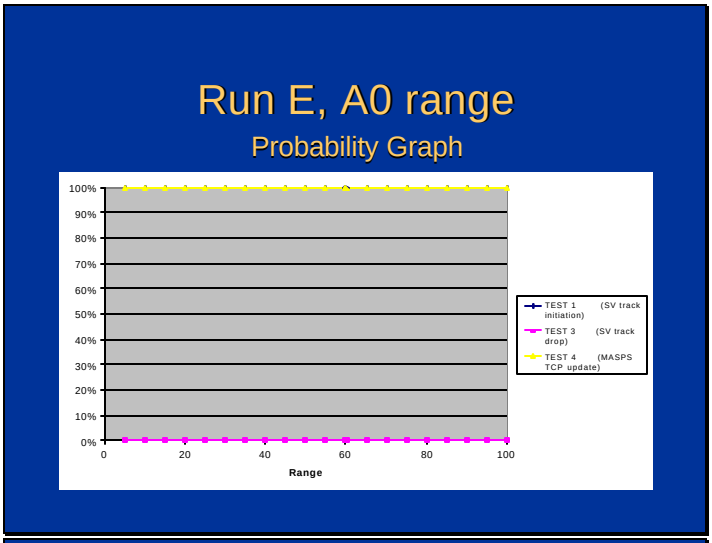

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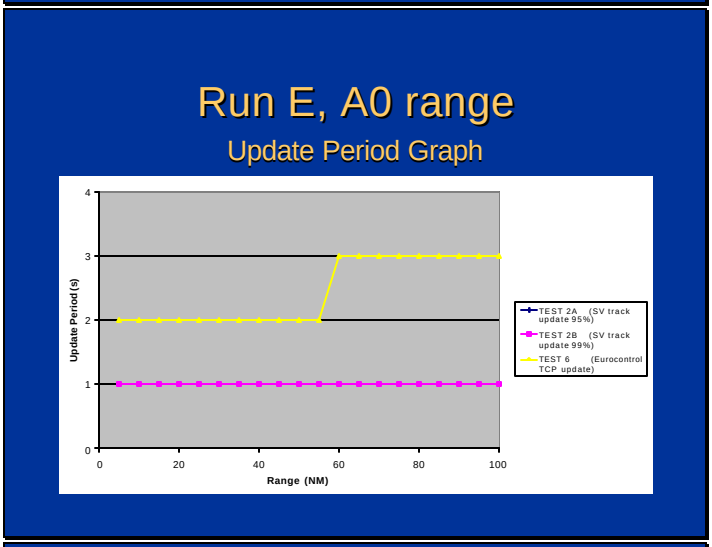

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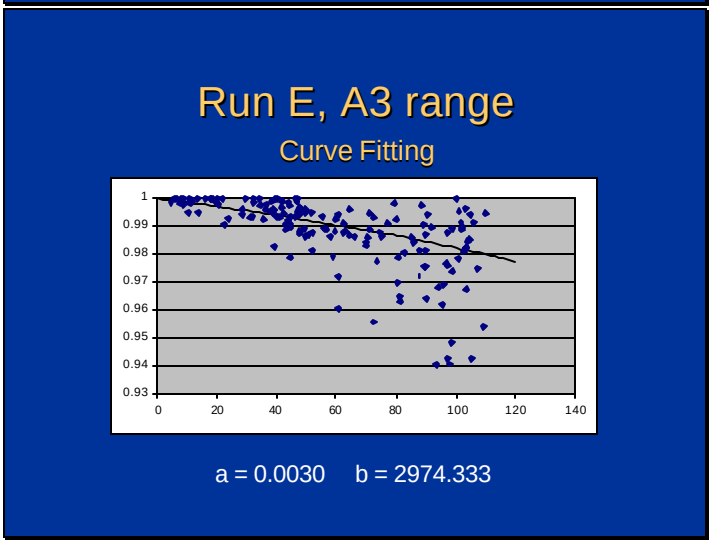

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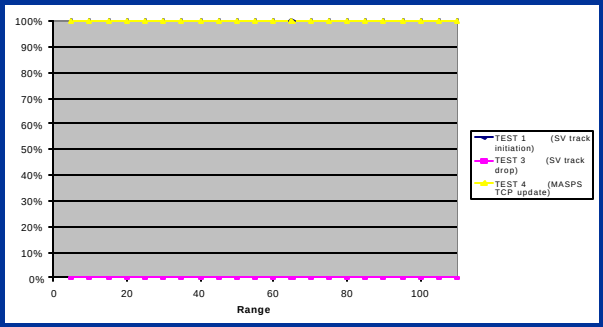
Run E, A3 range

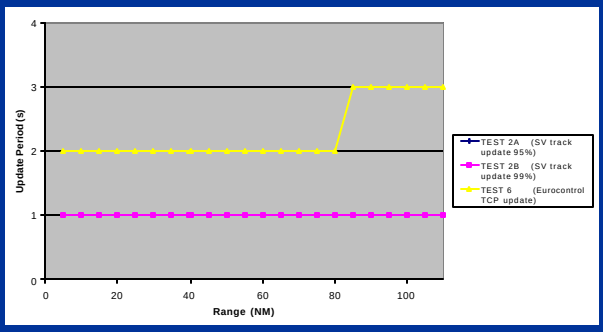
Probability Graph



Slide 53

Run E, A3 range

Update Period Graph



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Test Results

Simultaneous Approach

Run	SV Track Initiation	SV track update (95%)		SV track update (99%)		SV track drop	Pass/ Fail
	% at 10nm (>95%)	0.165nm (<1.5s)	0.411nm (<3s)	0.165nm (<3s)	0.411nm (<7s)	<1%	
Run A Range (A0)	95.60	pass	pass	pass	pass	< 90nm	Pass
Run A Range (A3)	99.90	pass	pass	pass	pass	<75nm	Pass
Run B Range (A0)	100.00	pass	pass	pass	pass	<125nm	Pass
Run B range (A3)	100.00	pass	pass	pass	pass	<165nm	Pass
Run C Range (A0)	99.97	pass	pass	pass	pass	<75nm	Pass
Run C Range (A3)	99.97	pass	pass	pass	pass	<80nm	Pass
Run D Range (A1)	99.83	pass	pass	pass	pass	<25nm	Pass
Run D Range (A3)	99.43	pass	pass	pass	pass	<20nm	Pass
Run E Range (A0)	100.00	pass	pass	pass	pass	within data	Pass
Run E Range (A3)	100.00	pass	pass	pass	pass	within data	Pass

= pass

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Test Results
Aid to Visual Acquisition

Run	SV Track Initiation	SV track update (95%)		SV track update (99%)		SV track drop	Pass/ Fail
	% at 10nm (>95%)	3nm (<3s)	10nm (<5s)	3nm (<6s)	10nm (<10s)	<1%	
Run A Range (A0)	95.60	pass	1	pass	2	< 90nm	Pass
Run A Range (A3)	99.90	pass	2	pass	2	<75nm	Pass
Run B Range (A0)	100.00	pass	1	pass	2	<125nm	Pass
Run B range (A3)	100.00	pass	1	pass	1	<165nm	Pass
Run C Range (A0)	99.97	pass	2	pass	2	<75nm	Pass
Run C Range (A3)	99.97	pass	1	pass	2	<80nm	Pass
Run D Range (A1)	99.83	pass	2	pass	2	<25nm	Pass
Run D Range (A3)	99.43	pass	2	pass	3	<20nm	Pass
Run E Range (A0)	100.00	pass	1	pass	1	within data	Pass
Run E Range (A3)	100.00	pass	1	pass	1	within data	Pass

= pass

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Test Results
Conflict and Collision Avoidance

Run	SV Track Initiation	SV track update (95%)		SV track update (99%)		SV track drop	Pass/ Fail
	% at 20nm (>95%)	3nm (<3s)	20nm (<7s)	3nm (<6s)	20nm (<14s)	<1%	
Run A Range (A0)	87.60	pass	3	pass	3	< 90nm	Fail
Run A Range (A3)	99.00	pass	3	pass	4	<75nm	Pass
Run B Range (A0)	99.97	pass	2	pass	2	<125nm	Pass
Run B range (A3)	100.00	pass	1	pass	2	<165nm	Pass
Run C Range (A0)	99.27	pass	3	pass	4	<75nm	Pass
Run C Range (A3)	99.47	pass	2	pass	3	<80nm	Pass
Run D Range (A1)	36.97	pass	17	pass	25	<25nm	Fail
Run D Range (A3)	2.00	pass	72	pass	100	<20nm	Fail
Run E Range (A0)	100.00	pass	1	pass	1	within data	Pass
Run E Range (A3)	100.00	pass	1	pass	1	within data	Pass

= pass

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Test Results
Separation Assurance and Sequencing

Run	SV Track Initiation	SV track update (95%)		SV track update (99%)		SV track drop	Pass/ Fail
	% at 40nm (>95%)	20nm (<7s)	40nm (<12s)	20nm (<14s)	40nm (<24s)	<1%	
Run A Range (A0)	40.90	3	16	3	23	< 90nm	Fail
Run A Range (A3)	66.00	3	9	4	11	<75nm	Fail
Run B Range (A0)	97.47	2	3	2	4	<125nm	Pass
Run B range (A3)	99.60	1	2	2	3	<165nm	Pass
Run C Range (A0)	69.53	3	8	4	12	<75nm	Fail
Run C Range (A3)	77.83	2	6	3	9	<80nm	Fail
Run D Range (A1)	fail	17	fail	25	fail	<25nm	Fail
Run D Range (A3)	fail	72	fail	100	fail	<20nm	Fail
Run E Range (A0)	100.00	1	1	1	1	within data	Pass
Run E Range (A3)	100	1	1	1	1	within data	Pass

= pass

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Test Results
Flight Path Deconfliction and Planning

Run	SV Track Initiation % at 90nm (>95%)	MASPS TCP update % at 90nm (>95%)	SV track drop <1%	Pass/ Fail
Run A Range (A0)	1.83	8.87	< 90nm	Fail
Run A Range (A3)	0.03	1.07	<75nm	Fail
Run B Range (A0)	30.17	53.73	<125nm	Fail
Run B range (A3)	69.53	93.47	<165nm	Fail
Run C Range (A0)	0.10	1.90	<75nm	Fail
Run C Range (A3)	0.23	3.37	<80nm	Fail
Run D Range (A1)	fail	fail	<25nm	Fail
Run D Range (A3)	fail	fail	<20nm	Fail
Run E Range (A0)	100.00	100.00	within data	Pass
Run E Range (A3)	100.00	100.00	within data	Pass

= pass

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Test Results
EUROCONTROL SV Update and TCP Update

Eurocontrol SV Update		
Run	TCP Update 150nm (<10s)	Pass/ Fail
Run A Range (A0)	fail	Fail
Run A Range (A3)	fail	Fail
Run B Range (A0)	fail	Fail
Run B range (A3)	fail	Fail
Run C Range (A0)	fail	Fail
Run C Range (A3)	fail	Fail
Run D Range (A1)	fail	Fail
Run D Range (A3)	fail	Fail
Run E Range (A0)	data unavailable	data unavailable
Run E Range (A3)	data unavailable	data unavailable

Eurocontrol TCP Update		
Run	TCP Update 150nm (<24s)	Pass/ Fail
Run A Range (A0)	fail	Fail
Run A Range (A3)	fail	Fail
Run B Range (A0)	fail	Fail
Run B range (A3)	fail	Fail
Run C Range (A0)	fail	Fail
Run C Range (A3)	fail	Fail
Run D Range (A1)	fail	Fail
Run D Range (A3)	fail	Fail
Run E Range (A0)	data unavailable	data unavailable
Run E Range (A3)	data unavailable	data unavailable